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VOL VIII

NORTHROP

Electronics Division

☐ This submittal applies to AN/BRN-7 (Submarine Ω) only.

☐ This submittal applies to AN/SRN-( ) (Hydrofoil Ω) only.

☒ This submittal applies to both AN/BRN-7 and AN/SRN-( ).

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NORT 73-48

AN/BRN-7 COMPUTER PROGRAM SPECIFICATION

Volume VIII

NAVIGATION SUBPROGRAM DESIGN

October 12, 1973

ACCESSION for
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Approved by

G. W. Hauser
Director, Engineering
Navigation Department

Volume VIII
of the
AN/BRN-7 OMEGA COMPUTER
PROGRAM SPECIFICATION

Volume

I	Performance Specification
II	Design Specification
III	Synchronization Subprogram Design
IV	OMEGA Processing Subprogram Design
V	Tracking Filter Subprogram Design
VI	Kalman Filter Subprogram Design
VII	Propagation Prediction Subprogram Design
VIII	Navigation Subprogram Design
IX	Executive Subprogram Design
X	Control-Indicator Subprogram Design
XI	Built-in Test Subprogram Design
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SECTION 1

SCOPE

1.1 IDENTIFICATION

Volume I, Submarine OMEGA Computer Program Performance Specification, defines the functional requirements for the Submarine OMEGA Computer Program which is used by the AN/ARN-99 OMEGA Navigation Set. The Navigation set and the OMEGA program together comprise the Submarine OMEGA Navigation System. The tape which defines the computer program is entitled AN/BRN-7 Navigation Program.

Volume II, Submarine OMEGA Computer Program Design Specification, allocates the functional requirements of Volume I to the computer routine and sub-program level.

This volume describes the subprogram designated as Navigation, which has two abbreviations in the program listing (Volume XIII) due to the fact that NAVIGATION is composed of two routines: the Velocity Processing Routine with the abbreviation VP; and the RIJ Update Routine with the abbreviation RU.

1.2 SUBPROGRAM TASKS

1.2.1 Velocity Processing (See Figure 1)

a) The incoming Velocity and Heading data must be read from the analog-to-digital synchro inputs, then smoothed if necessary.

b) The Velocity/Heading mode marker must be checked to determine whether the synchro or manual inputs will be used.

c) Uncorrected velocity is then resolved to the R_2 and R_3 reference axes.

d) Velocity is corrected, using corrections from the Combinational Filter.

1.2.2 RIJ Update

a) The rotational correction terms must be calculated.

b) The correction terms are then used to rotate the RIJ matrix.

c) The Wander Azimuth Angle is computed for use by other programs.

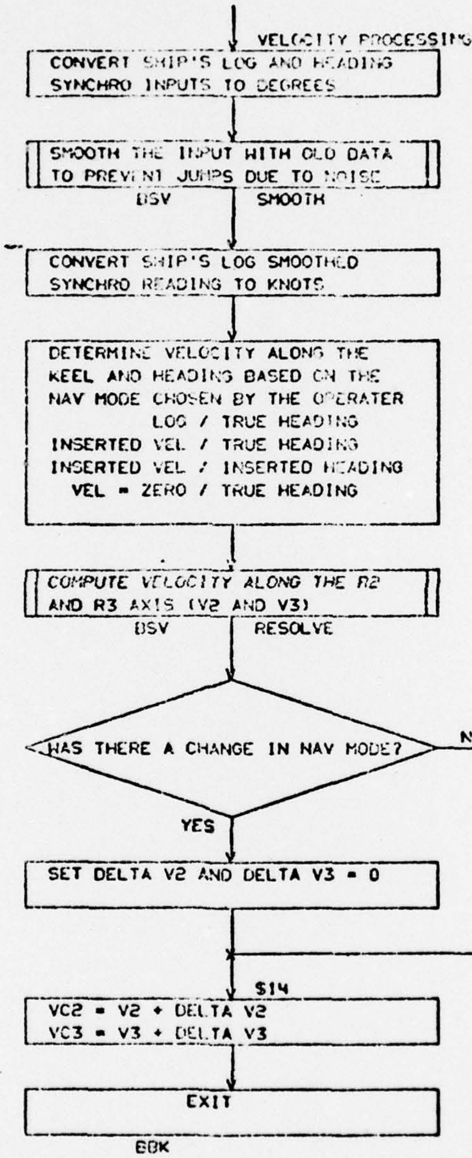


FIGURE 1 VELOCITY PROCESSING

SECTION 2

APPLICABLE DOCUMENTS

a) Submarine OMEGA Computer Program Performance Specifications, Volume I of the Submarine OMEGA Computer Program Specification.

Applicable Sections:

3.1.1 Omega Task and System Breakdown
3.3.13 Velocity and Heading Processing
3.3.14 Navigation

b) Submarine OMEGA Computer Program Design Specification, Volume II of the Submarine OMEGA Computer Program Specification.

c) NORT 68-66, NAP70 User's Manual, July 1968.

d) NORT 68-115A, Detailed Description of NDC-1070 Computer Instructions, Revision A, February 1970.

e) NORT 69-87A, NDC-1070 Flow Chart Program, User's Manual.

SECTION 3

REQUIREMENTS

In order to understand the program description contained in the following pages, it is necessary that the reader will have become familiar with the associated functional requirements found in Volume I, Performance Specification, and with the subprogram allocation found in Volume II, Design Specification.

3.1 DETAILED DESCRIPTION

3.1.1 Reference Labels to Flow Diagrams

The code used to reference the particular block in the flow diagrams, Section 3.2, is as follows: The first number is the page number found in the upper right corner of the diagrams. This will be followed by a slash sign (/) to separate the page number from the block designator. The designator will either be a mnemonic label (e.g., TEST SYNC), a local label indicated by a dollar sign ($), or an integer. The two types of labels reference the particular information block, on the given page, to which the label is attached. The integer number, n, means that the referenced block is the n^{th} block from the top of the page; P8/3 would refer to page 8 and the third information designation down.

Finally, the label P1/$2+3 refers to page 1, and the 3rd information block after the label $2. Similarly, P2/7,8,9 refers to page 2 and blocks 7 through 9.

3.1.2 Discussion

The Navigation Subprogram is handled by the Five-Millisecond Interrupt Routine of the Executive Subprogram, and is separated into two non-Ω-tasks: Velocity Processing (VP), and RIJ Update (RU). As part of the non-Ω-task table these routines are called at a frequency of 10/second.

a) Velocity Processing: This routine processes the velocity and heading data which is input from either the E.M. Ship's Log (velocity) and the Mark 19 Repeater (heading), and/or the respective manual inputs from the Control-Indicator. If the data are from the external sources, the inputs will be smoothed before processing. This is not necessary for the manual inputs.

   The submarine velocity input is resolved into the system axes (R_2 and R_3) and then corrected by velocity increments from the combinational filter.

b) RIJ Update: The iterative updating of the position matrix is performed by converting the velocity over the last iteration into the effective angular rotation about each of the system axes. These rotations are then used to generate the rotation update matrix. The update matrix is multiplied by the previous position matrix to yield the change of position. Periodically the Kalman routine will be generating positional corrections. These will be added to and processed with the rotations generated from the velocity.

3.1.3 Flow Diagram Description

3.1.3.1 Velocity Processing

P1/VELOCITY PROCESSING

Sets up address of synchro data and index to read the synchro inputs.

a) Smoothing:

p1/VELOCITY PROCESSING \$1 through p2/1

This loop reads and, if necessary, smooths the incoming data. The first input is heading. The loop through \$2 is the process of data accumulation.

Set $Z = (\psi_A - \psi_{Ao})$

Test $|Z| > 4.4^o$?

Yes: $\psi_A = 0.02 Z + \psi_{Ao}$

Continue

No: $\psi_{Ao} = \psi_A$

The second time through the loop, velocity is smoothed.

Set $Z = (V_{TAS} - V_{TASo})$

Test $|Z| > 12.2$ knots ?

Yes: $V_{TAS} = 0.02\ Z + V_{TASo}$

Continue

No: $V_{TASo} = V_{TAS}$

b) Check Mode:

p2/2 through p3/$33

The program must check the velocity/heading mode set by the operator via the Control-Indicator: if MAN Marker true, use manual velocity heading inputs; if VEL Marker true, use manual velocity and smoothed heading; if LOG Marker true use both smoothed values above. Now let V_{AT} and ψ_A = velocity and heading input from either the output of the smoothing routine or the manual input (Control-Indicator).

c) Uncorrected Velocity Resolution:

p3/$33 + 1

Subroutine RESOLVE

$$V_2 = V_{AT} \text{ Sin } (\Theta_p + \psi_A)$$

$$V_3 = V_{AT} \text{ Cos } (\Theta_p + \psi_A)$$

p3/$33 + 2 through p4/2

Override using Program Monitor Unit.

d) Velocity Corrected:

p4/$12 through p4/$14

If a new NAVMODE is not indicated, then set:

$$V_{C2} = V_2 + \delta V_2$$

$$V_{C3} = V_3 + \delta V_3$$

3.1.3.2 RIJ Update

a) Rotational Correction Terms:

p5/RIJ UPDATE through p5/RIJ UPDATE + 1

$$\Delta\theta_2 = -\left[1 + e\,(1-2\,r_{11}^{\,2} + r_{31}^{\,2} - r_{21}^{\,2})\right] \frac{V_{C3}\,\Delta t_{NAV}}{R_o}$$

$$-2e\; r_{21}\; r_{31} \frac{V_{C2}\,\Delta t_{NAV}}{R_o} + \delta\theta_2$$

$$\Delta\theta_3 = \left[1 + e\,(1-2\,r_{11}^{\,2} - r_{31}^{\,2} + r_{21}^{\,2})\right] \frac{V_{C2}\,\Delta t_{NAV}}{R_o}$$

$$+2e\; r_{21}\; r_{31} \frac{V_{C3}\,\Delta t\ NAV}{R_o} + \delta\theta_3$$

p5/RIJ UPDATE +2

Set $\delta\theta_2 = \delta\theta_3 = 0$

b) R_{ij} Matrix Rotation:

p5/RIJ UPDATE +3

Subroutine ROTATE RIJ's

$$[\theta] = \begin{bmatrix} \frac{-(\Delta\theta_2^{\,2} + \theta_3^{\,2})}{2} & \Delta\theta_3 & -\Delta\theta_2 \\ -\Delta\theta_3 & \frac{-\Delta\theta_3^{\,2}}{2} & \frac{\Delta\theta_2\,\Delta\theta_3}{2} \\ \Delta\theta_2 & \frac{\Delta\theta_2\,\Delta\theta_3}{2} & \frac{-\Delta\theta_2^{\,2}}{2} \end{bmatrix}$$

$$R_{ij_{new}} = R_{ij_{old}} + [\theta]_{3x3}\, R_{ij_{old}}$$

c) Wander Azimuth Angle:

p5/RIJ UPDATE +4

$$\theta_p = TAN^{-1}\left[\frac{r_{21}}{r_{31}}\right]$$

Exit

3.1.4 Description of Subroutines Used by the Navigation Subprogram

a) SMOOTH (page 6)

The subroutine will smooth a noisy data input with the last input. As indicated in 3.1.3.1-a, the new data less the old data is checked to see whether it is greater in absolute value than 4.4° = 12.2 knots (i.e. on synchro input reference).

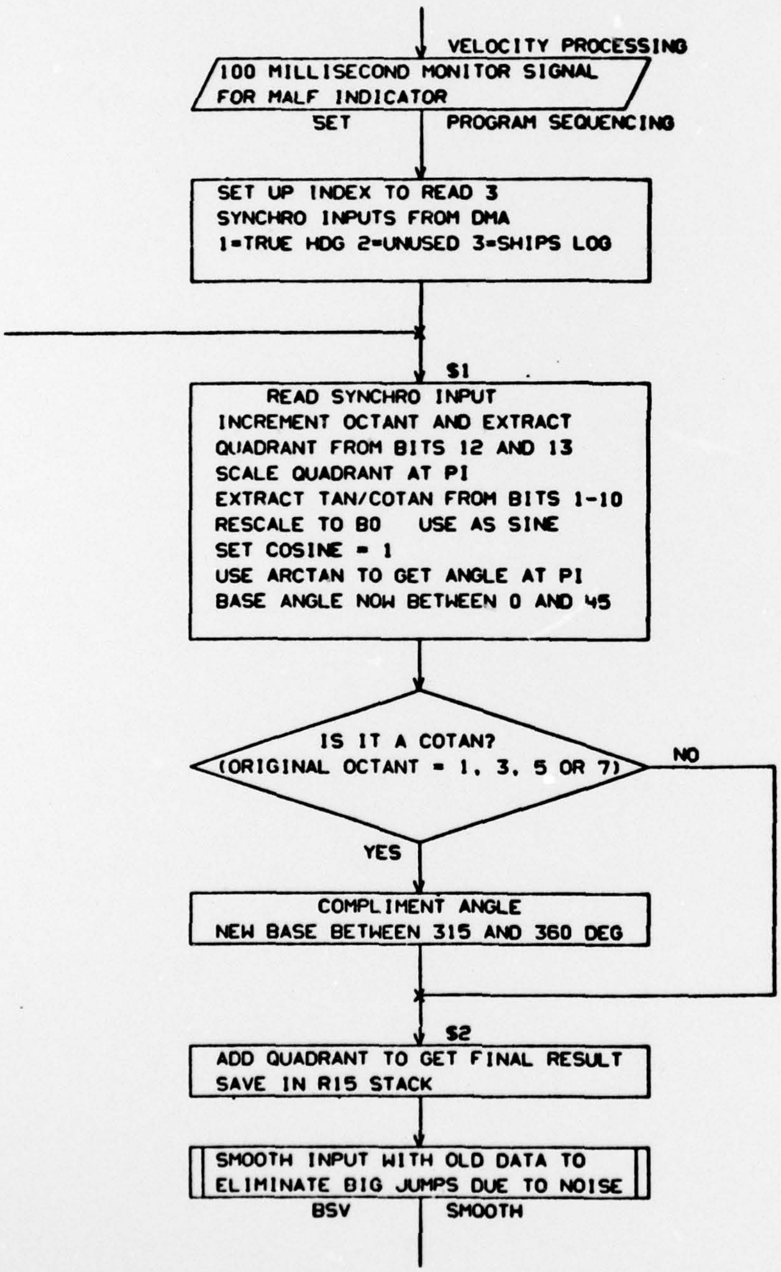
If so, then it is smoothed as indicated.

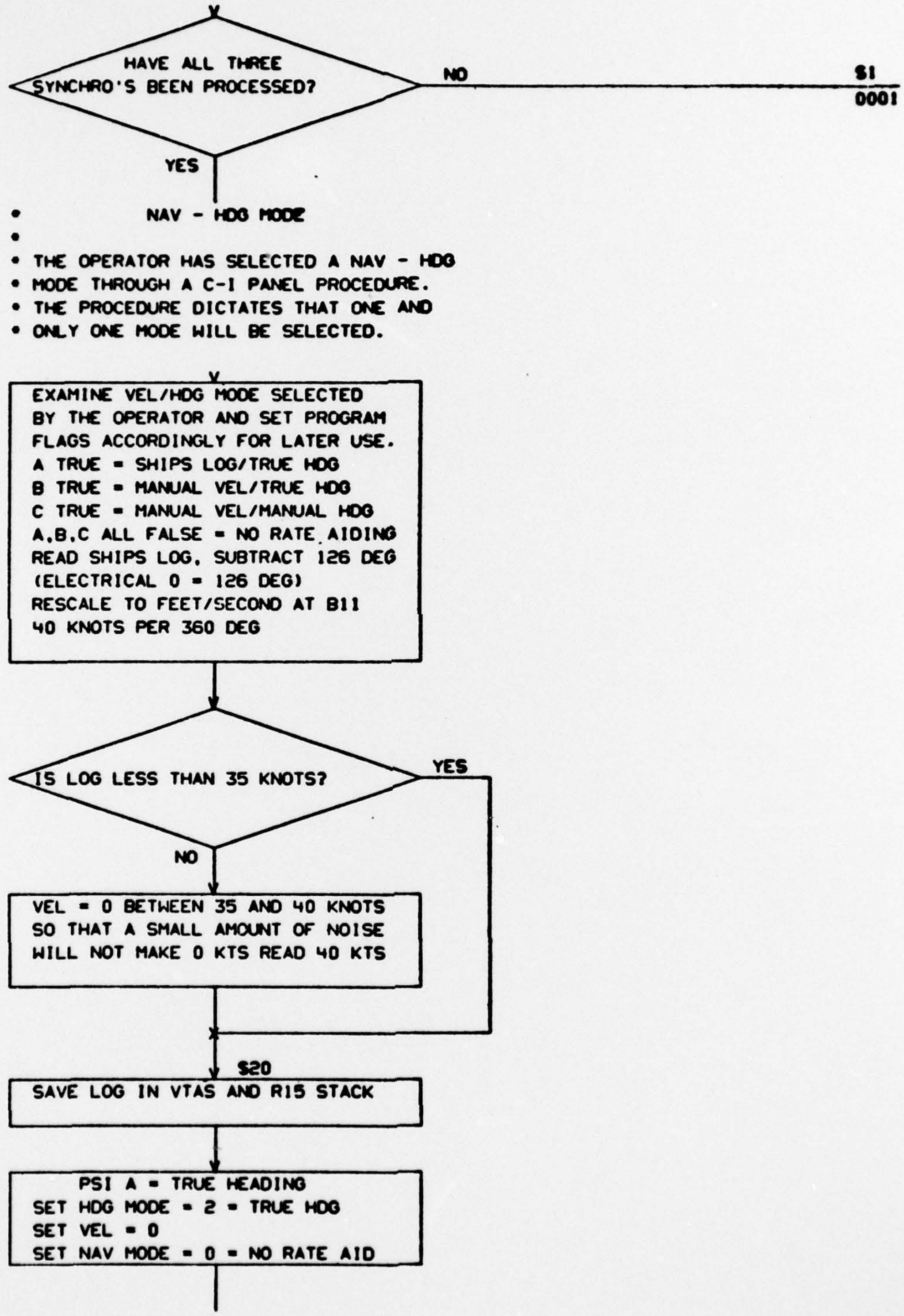
If not, then the input data is used.

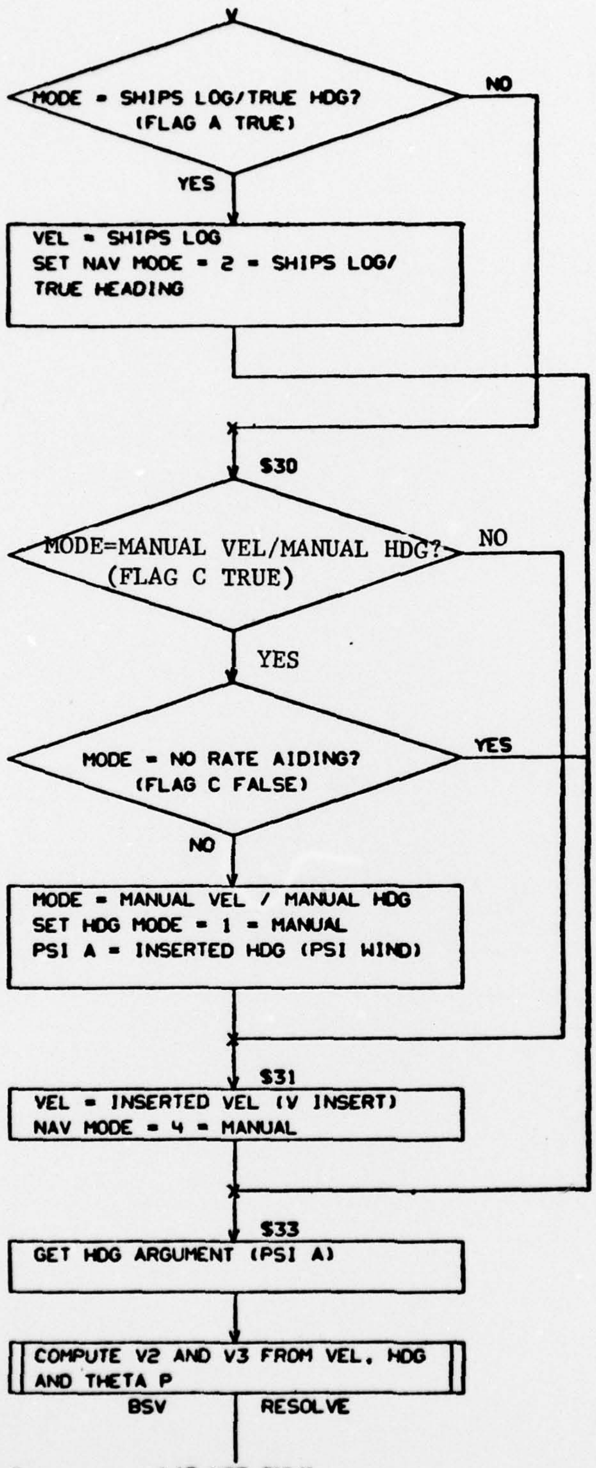
3.2 FLOW CHARTS

The Navigation Subprogram flow charts are presented on the following pages.

```
*                    VELOCITY PROCESSING
*
* THIS PROGRAM READS AND CONVERTS THE TWO SYNCHRO INPUTS (SHIPS LOG
* AND TRUE HEADING) INTO A USABLE FORM.  IT COMPUTES THE VELOCITY
* ALONG THE R2 AND R3 AXIS BASED ON THE NAVAGATION MODE SELECTED BY
* THE OPERATOR. IT IS A NON OMEGA TASK THAT IS EXECUTED EVERY
* TENTH OF A SECOND.
*
```

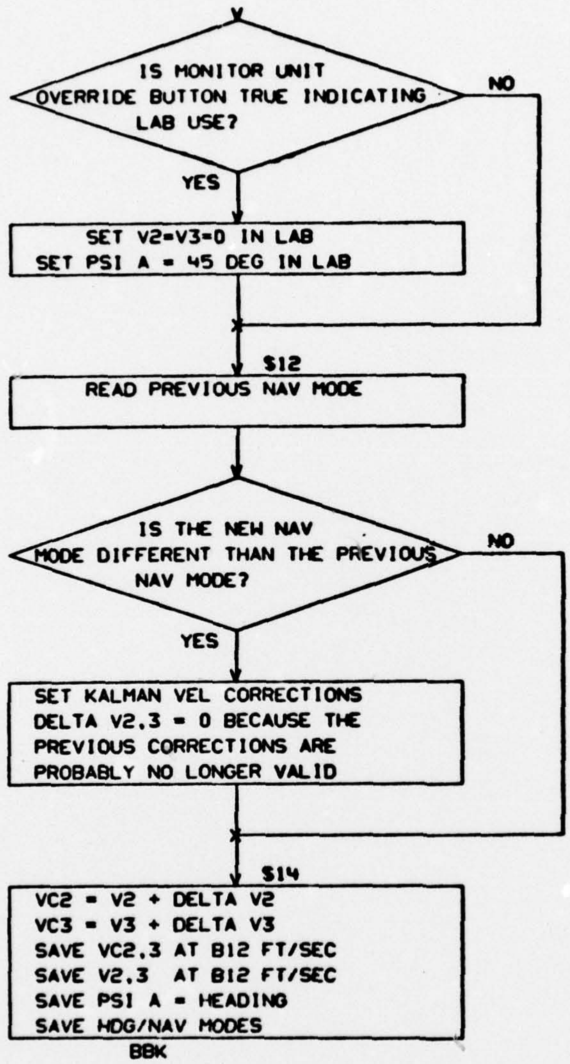



HAVE ALL THREE SYNCHRO'S BEEN PROCESSED?
NO
S1
0001
YES
• NAV - HDG MODE
•
• THE OPERATOR HAS SELECTED A NAV - HDG
• MODE THROUGH A C-I PANEL PROCEDURE.
• THE PROCEDURE DICTATES THAT ONE AND
• ONLY ONE MODE WILL BE SELECTED.
EXAMINE VEL/HDG MODE SELECTED BY THE OPERATOR AND SET PROGRAM FLAGS ACCORDINGLY FOR LATER USE.
A TRUE = SHIPS LOG/TRUE HDG
B TRUE = MANUAL VEL/TRUE HDG
C TRUE = MANUAL VEL/MANUAL HDG
A,B,C ALL FALSE = NO RATE AIDING
READ SHIPS LOG, SUBTRACT 126 DEG
(ELECTRICAL 0 = 126 DEG)
RESCALE TO FEET/SECOND AT B11
40 KNOTS PER 360 DEG
IS LOG LESS THAN 35 KNOTS?
YES
NO
VEL = 0 BETWEEN 35 AND 40 KNOTS SO THAT A SMALL AMOUNT OF NOISE WILL NOT MAKE 0 KTS READ 40 KTS
S20
SAVE LOG IN VTAS AND R15 STACK
PSI A = TRUE HEADING
SET HDG MODE = 2 = TRUE HDG
SET VEL = 0
SET NAV MODE = 0 = NO RATE AID



- LAB USE ONLY
- ALLOW LAB OPERATOR TO OVERRIDE
- VEL/HDG INPUTS FROM THE PROGRAM

• MONITOR UNIT



```
*           RIJ UPDATE
*
* THIS IS A NON OMEGA TASK THAT UPDATES
* CRAFT POSITION 10 TIMES A SECOND
```

RIJ UPDATE

INTEGRATE COMPUTED VELOCITY
VC2,3 * DELTA T / RHO = ANG2,3
RHO = EARTH EQUATORIAL RADIUS
TO GET ANGULAR CHANGE ALONG
R2, R3

COMPUTE DELTA THETA 2
= -(1 + E(1-2R11**2 + R31**2
- R21**2))*(ANG 3) - 2ER21R31
*(ANG 2) + KALMAN CORRECTION 2

COMPUTE DELTA THETA 3
= (1 + E(1-2R11**2 - R31**2
+ R21**2))*(ANG 2) + 2ER21R31
(ANG 3) + KALMAN CORRECTION 3

CLEAR KALMAN CORRECTIONS 2,3
(THEY WILL BE NON ZERO AT MOST
ONCE PER 10 SECONDS)

UPDATE RIJ MATRIX WITH DELTA
THETA 2, DELTA THETA 3

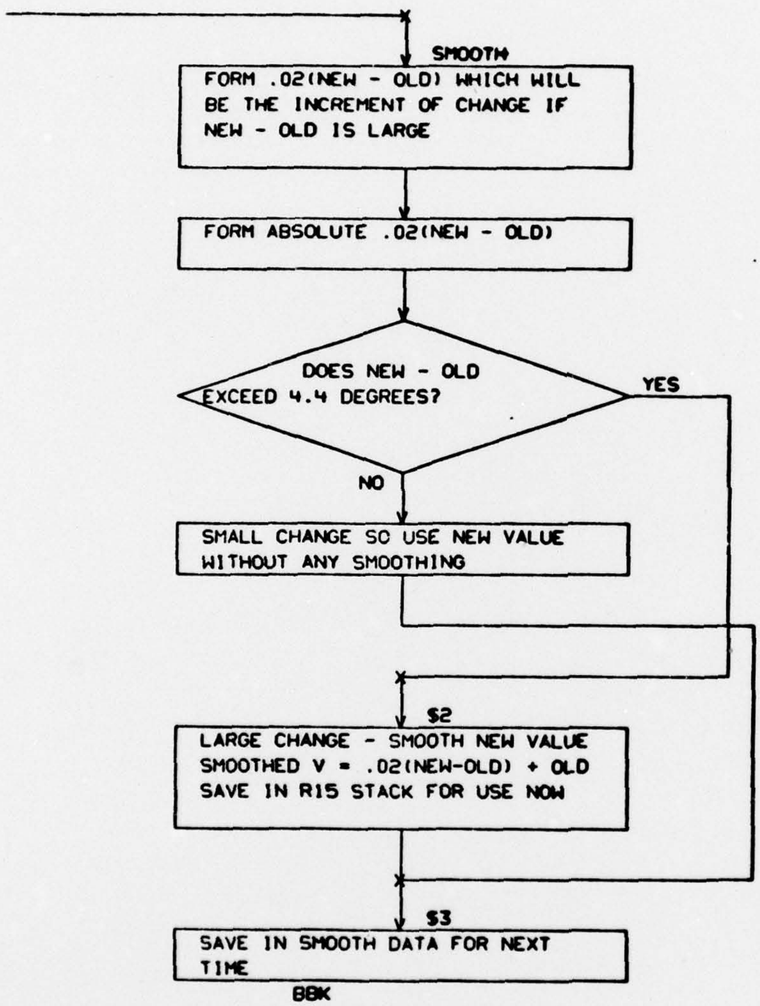
BSV ROTATE RIJS

COMPUTE THETA P = ATAN R21/R31
SAVE THETA P, SIN (THETA P)
AND COS (THETA P) FOR OTHER
PROGRAMS

BBK

PAGE 0006

- * SYNCHRO SMOOTHING ROUTINE
- *
- * THIS PROGRAM WILL SMOOTH THE NEW
- * SYNCHRO INPUT IF IT IS SUBSTANTIALLY
- * DIFFERENT THEN THE OLD VALUE



3.3 COMPUTER SUBPROGRAM ENVIRONMENT

3.3.1 Computer Subprogram Tables

None.

3.3.2 Computer Subprogram Temporary Storage

All temporary storage for the Navigation routine is contained in the R15 pushdown stack.

3.3.3 Input/Output Formats

DMA words $1A_{16}$ through IF_{16} receive inputs from the Analog-to-Digital Converter. One word is brought in during the last one-third of each 5-millisecond period, with all right words cycled every 40 milliseconds. DMA word 1A contains the true heading input and word 1B contains the ship's log input. Each of these inputs is from a synchro with either a tangent or cotangent in bits 1 to 12 of the input word. These bits define the synchro input within a single octant (45 degrees). Bits 14 to 15 of the input word define the correct octant. The first octant is 0 and bit 14 true defines the second octant. Bits 1 to 12 represent a tangent for octants 0,3,4, and 6; otherwise they contain a cotangent.

Word 1A converts directly to true heading. Word 1B is shifted 120° from zero so that it is necessary to subtract 120° from the synchro value before converting to velocity. The conversion factor is 40 knots per 360°.

3.3.4 Required System Library Subroutines

Subroutine	Functional Description (Section 3.1.3)	Flow Diagram	Subprogram Design Document (by Volume Number)
RESOLVE	(a)	3/$33 + 1	XII Common Subroutine
ATAN	(b)	60/RIJ UPDATE + 4	XII Common Subroutine
SIN/COS	(b)	60/RIJ UPDATE + 4	XII Common Subroutine
ROTATE RIJ's	(b)	Page 61	XII Common Subroutine